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EFFECT OF TRUNK INJECTION OF THE GROWTH REGULATORS MBR 18337, EL-500 AND PP 333 ON SPROUT GROWTH IN SILVER MAPLE

Report No 84-319-K

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ABSTRACT

Two-year-old silver maple (Acer saccharinum L) trees were pruned and trunk injected with methanolic solutions of the growth regulators MBR 18337, EL-500 and PP 333. All the growth regulators caused a significant reduction in the growth of sprouts that formed, and a significant increase in the number of internodes per unit sprout length, when measurements were made three months after injection. A high dose of MBR 18337 (5 mg/tree) was phytotoxic, although this was temporary.

job	file	date	report no.
740634-559-031	834.1	November 22, 1984	84-319-K

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EXECUTIVE SUMMARY

EFFECT OF TRUNK INJECTION OF THE GROWTH REGULATORS MBR 18337, EL-500 AND PP 333 ON SPROUT GROWTH IN SILVER MAPLE

G.P. Arron

The control of tree growth under both transmission and distribution lines is a major expense for all electric utilities. Manual pruning of trees under distribution lines on city streets is routinely carried out by Ontario Hydro and municipal utilities at intervals of one to four years depending on the rate of growth of the species involved and the amount of line clearance required. Extension of such pruning cycles would result in a substantial cost saving. Many chemicals have been developed by the horticultural industry to retard or control the growth of fruit trees, and some of these have proved to be useful in the control of growth of trees under distribution lines. Such chemicals have been applied as foliar-sprays but more recently trunk injection has been introduced with the obvious advantages of avoidance of drift, more precise dosage control, and greater application safety.

The present study was conducted to provide evidence as to the applicability of trunk injection of growth regulators in extending the pruning cycle. The effects of trunk injection of three new growth regulators, PP 333 (paclobutrazol), EL-500 (flurprimidol) and MBR 18337 (no common name), were determined on sprout formation in pruned two-year-old silver maple (Acer saccharinum L) trees grown in the greenhouse. Basswood (Tilia americana L) and white ash (Fraxinus americana L) trees were also included in this study but sprout growth in these species was extremely slow and data obtained with these species will be included as an addendum to the present report at a later date.

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Each growth regulator was applied in a range of three dose rates. Both EL-500 and PP333 caused a decrease of between 50 and 60% in the number of sprouts found on the experimental trees when compared to the control by the end of the three month experimental period. All the growth regulators were effective in that significantly shorter sprouts were produced in the silver maple trees than in control trees. All the growth regulators caused the production of sprouts both above and below the injection point on the tree stems whilst sprouts only formed above the injection point on control trees. With both EL-500 and PP 333 the mean length of sprouts produced above the injection point was less than the mean length of sprouts produced below, and this suggests that both these growth regulators move predominantly upwards in the tree stem rather than downwards. MBR 18337 had no such differential effect on the mean length of the sprouts produced and thus is thought to be ambimobile, moving both upwards in the xylem and downwards in the phloem. Various dose rates of EL-500 and PP 333 caused a significant increase in the number of internodes per unit length in the sprouts produced above the injection point over the control and this confirms that the mode-of-action of these two chemicals is as an inhibitor of gibberellin biosynthesis, resulting in internode compression and long-term growth retardation. MBR 18337 did not have such a pronounced effect on the internode length of sprouts. High doses of MBR 18337 caused initial sprout growth to be distorted, with twisted and cupped leaves, although later in the experiment the foliage appeared normal. Such phytotoxic effects were not observed with the dose rates used of either EL-500 or PP333.

In light of the results described above it is recommended that the effectiveness of trunk injection of the growth regulators EL-500 and PP 333 should be examined in the field in those vigorously sprouting tree species which cause problems under distribution lines on the city streets of Ontario.

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To Mr. F.J. Kee
Director of Research

EFFECT OF TRUNK INJECTION OF THE GROWTH REGULATORS MBR 18337, EL-500 AND PP 333 ON SPROUT GROWTH IN SILVER MAPLE

1.0 INTRODUCTION

The control of tree growth under both transmission and distribution lines is a major expense for all electric utilities. Manual pruning of trees under distribution lines on city streets is routinely carried out by Ontario Hydro and municipal utilities at intervals of one to four years depending on the rate of growth of the species involved and the amount of line clearance required (Gardner, 1971; EPRI, 1979). The extension of such pruning cycles by one or more years would result in a substantial cost saving (Gardner, 1971).

Much effort has been spent in developing chemicals for the horticultural industry to retard or control the growth of both woody and herbaceous plants. Although most such chemicals have been developed for tree thinning, fruit set and size control and harvest timing, some have proved to be useful in the control of the growth of trees under distribution lines on city streets. Naphthaleneacetic acid (NAA), one of these chemicals, is a component of a tree wound dressing routinely applied by Ontario Hydro to prevent infection of the tree by bacteria and fungi and to inhibit sprouting. The effectiveness of chemicals such as NAA applied either in foliar sprays or in tree wound dressings has been investigated extensively by Research Division in recent years (Effer, 1969a, 1969b, 1970a, 1970b; Gardner, 1970, 1971; Medicky, 1970; Spencer, 1974). The injection of such chemicals into the tree trunk (Sachs et al, 1977) offers obvious advantages such as avoidance of drift, more precise dosage control, and greater application safety (Roberts et al, 1979). The Electric Power Research Institute (EPRI) has recently published two comprehensive reports on studies performed across the US on trunk injection of various growth regulators (EPRI, 1979, 1982). Although it was shown that injection of aqueous growth regulators into trees could effectively reduce sprout growth (EPRI, 1979, 1982; Roberts et al, 1979; Domir and Roberts,

1981), there was significant variability of regrowth among trees of any given species. Variability was observed not only among trees of the same species treated under different geographic and climatic conditions, but also among treated trees growing at one location under the same climatic conditions (EPRI, 1982). Such variability may occur for several reasons, including heredity, vigor of the tree (resistance of tree to chemical agents, water stress), developmental stage of the tree at treatment time, canopy size, time of year of chemical application, and volume of chemical applied (eg small volume of high concentration of growth regulator or large volume of low concentration) (EPRI, 1982; CEA, 1982). Since both climatic conditions and species composition vary between Canada and the US, the effectiveness of the growth regulators reported by EPRI (1982) may be different north of the border. The Canadian Electrical Association (CEA) initiated studies on the trunk injection of growth regulators in 1983, although field experiments are not expected to start until late 1984 or 1985. CEA proposed an investigation of the effects of trunk injection of the three growth regulators, maleic hydrazide [1,2-dihydro-3, 6-pyridazine dione], dikegulac [sodium salt of 2,3:4,6-bis-O-(1-methylethylidene)-O(-L-xylo-2-hexulofuranosonic acid) and PP 333 [common name paclobutrazol, (2R,3R+2S,3S)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl)pentan-3-ol] after trunk injection into various problem tree species at test sites across Canada. Since CEA initiated these studies there have been reports of effective control of sprout growth by new plant growth regulators such as MBR 18337 {N-[4-(ethylthio)-2-(trifluoromethyl)phenyl]-methane-sulfonamide} in white ash (Fraxinus americana L) and red maple (Acer rubrum L) (Sterrett et al, 1983) and by EL-500 {common name flurprimidol, α-(1-methylethyl)-α-[4-(trifluorome-thoxy)phenyl]-5-pyrimidine-methanol} in unspecified woody plants (G.C. Turnbull pers. comm. to GPA, 1983).

The present study was conducted to determine the effectiveness of trunk injection of the three growth regulators, PP 333, EL-500 and MBR 18337, in reducing the growth of sprouts in pruned white ash, silver maple (Acer saccharinum L) and basswood (Tilia americana L) trees grown in the greenhouse. The experience gained from this study will prove useful before large-scale field studies are conducted with trunk injection of several growth regulators next year.

2.0 MATERIALS AND METHODS

2.1 Plant Material

Two-year-old white ash, basswood and silver maple trees were a gift from the Ontario Ministry of Natural Resources (collected

from the Midhurst Station). The ash and basswood were approximately 0.5 m in height and the silver maple approximately 1.5 m. All the trees were planted in 30 or 37 cm pots in a one-to-one mixture of shredded topsoil (native sandy loam) and peat moss (Plant Products, Bramalea, Ontario) in late December 1983. The trees were placed in the greenhouse (maintained at 25°C) immediately after plotting, and the day length extended (16 h day, 8 h night) by illumination (photosynthetic photon flux density was 110 $\mu E\ m^{-2}\ s^{-1}$). The trees were watered at regular intervals and fertilizer (solution of 20-20-20 (NPK)) applied every two weeks. Approximately two to three weeks after planting 95% of both the silver maple and basswood trees had broken dormancy, whilst 90% of the white ash had broken dormancy within six weeks.

2.2 Growth Regulator Application

The growth regulators PP 333, EL-500 and MBR 18337 were obtained as gifts from Chipman Inc, Stoney Creek, Ontario; Elanco (Division Eli Lilly Canada Inc) London, Ontario; and 3M Agricultural Products, St. Paul, Minnesota, respectively. For a detailed description (full chemical name, mode-of-action, concentration of stock solutions) of the growth regulators used, see Appendix A.

The stock solutions of the growth regulators were diluted with methanol to give the desired range of concentrations.

Five months after planting, 90 trees were chosen from each species. Extremely small or large trees were discarded as being non-representative, since it was known that the response observed after injection of a given amount of growth regulator would be related to the size of the tree (EPRI, 1982). At random, nine trees were chosen for each growth regulator treatment. Holes were drilled at the base of the tree stem, between 4 and 5 cm above the soil surface. An electric drill with a 2 mm bit was used to make a hole approximately 10 mm deep and at an angle of approximately 45° to the vertical stem. Any shavings were removed from the hole and 50 µL of experimental solution injected into it with a 50 µL syringe. The hole was immediately covered with a dab of silicone grease to prevent the entry of infectious organisms. This injection technique was adopted after attempts to use the pressure injection technique described by Sterrett and coworkers (Sterrett and Creager, 1977; Sterrett, 1979) had failed. This latter method also calls for holes to be drilled, but injection of material is under pressure. After growth regulator injection in the present study, the trees were pruned to remove approximately one-third of the length of both any laterals and of the single major stem, should there be one. A record was made of the physical appear-

ance of each tree, carefully noting the location and length of the laterals and the length of the main stem. Control trees were treated in exactly the same manner as those injected with growth regulators, except that they received methanol alone (50 µL) rather than 50 µL of a methanolic solution of PP 333, EL-500 or MBR 18337 (see Appendix A). Small volumes of methanol have been shown to be non-phytotoxic to trees (Technical Data Sheet, PP 333, 1984).

2.3 Measurement of New Sprout Growth

The trees remained in the greenhouse for three months and then each was remeasured and by comparison with measurements taken at the time of growth regulator application the location and length of each new lateral were determined. The number of internodes in each new lateral was also noted. The silver maple trees sprouted prolifically whilst both the white ash and basswood trees sprouted poorly, following loss of many of the leaves on each plant. Since even these few sprouts did not appear until the end of the three month experimental period it was decided to remeasure all the white ash and basswood trees at a later date and to confine the present report to a discussion of the silver maple data. In three instances, only eight of the group of nine silver maple trees subjected to a particular treatment could be found at the end of the experiment. Data obtained at a later date on the effect of the three growth regulators on pruned white ash and basswood trees will be submitted as an addendum to this report.

3.0 RESULTS AND DISCUSSION

3.1 Phytotoxic Effects of the Growth Regulators MBR 18337, EL-500, and PP 333 on Sprouts Formed on Pruned Silver Maple Trees

By four or five weeks after injection of the growth regulator MBR 18337 (5 mg/tree) the initial sprout growth on many of the silver maple trees had a distorted shape, with twisted and cupped leaves and some shoot damage. Lower doses of the same growth regulator did not have such a pronounced effect. After another five weeks the foliage appeared normal. Neither EL-500 or PP 333, at any of the dose rates used, caused such phytotoxic effects in silver maple. Sterrett et al (1983) has reported similar phytotoxic responses of six-year-old white ash and red maple trees injected with high doses of MBR 18337 (6.4 and 12.8 mg/tree). The malformed growth observed by Sterrett was also temporary, as the foliage of later growth appeared normal both in the season of growth regulator application and in the following growing season. Hare (1984) has reported that EL-500 was not phytotoxic when applied to the foliage or bark of

two-year-old loblolly (Pinus taeda L) and slash (P. elliottii Engelm var. elliottii) pines, and PP 333 has been reported to exhibit little or no phytotoxicity towards woody plants (Technical Data Sheet, PP 333; 1984).

3.2 Effects of the Growth Regulators MBR 18337, EL-500 and PP 333 on the Number and Length of New Sprouts and the Number of Internodes Per Unit Length in Such Sprouts, in Pruned Silver Maple Trees

Thirteen weeks after the various growth regulators had been injected into the trees, the length of each sprout and the number of internodes in that sprout were recorded. Plant stems are divided anatomically into nodes and internodes, regions that alternate throughout the length of the stem. The nodes are the slightly enlarged portions of the stem where leaves and buds arise and where branches originate from the buds. An internode is the region between two successive nodes. The number of internodes in each new sprout and sprout length were recorded because both EL-500 and PP 333 have been shown to induce internode compression (see Appendix A), and thus it might be expected that application of these growth regulators would result in a decrease in sprout length with a concominant increase in the number of internodes per unit length in such sprouts. No effects of MBR 18337 on the number of internodes per unit sprout length have been reported. Data on internode frequency, especially from long-term studies, will be useful in determining the longevity of a growth regulator induced response. PP333 is thought to remain active in the plant for 12 to 18 months ie, two growing seasons (Technical Data Sheet PP333; 1984). A loss of activity of PP333 in the long-term might be detected in a lack of internode compression before any effects on overall sprout-length are observed.

The effects of trunk injection of various amounts of the three growth regulators on the number of new sprouts on a per tree basis, are given in Table 1. The number of new sprouts, expressed on a per tree basis, on silver maple trees treated with three different doses of EL-500 was significantly smaller than the number of new sprouts observed on control trees. The two higher doses of PP 333 (0.5 mg/tree and 2.5 mg/tree) also resulted in significantly fewer sprouts on treated trees, whilst the lowest dose of PP 333 and the high and low doses of MBR 18337 had no significant effect on the number of sprouts formed per tree. Trees treated with a medium dose of MBR 18337 (1.0 mg/tree) had significantly more new sprouts than control trees.

TABLE 1

EFFECTS OF TRUNK INJECTION OF VARIOUS AMOUNTS OF THE GROWTH REGULATORS MBR 18337, EL-500 AND PP 333 ON THE NUMBER OF NEW SPROUTS FORMED IN PRUNED SILVER MAPLE TREES

Parameter	Control	MBR 18377 mg/tree			EL-500 mg/tree			PP 333 mg/tree		
		0.2	1.0	5.0	1.0	5.0	25.0	0.1	0.5	2.5
Number of trees treated	9	9	9	8	8	9	8	9	9	9
Number of trees with sprouts	9	9	9	8	6	7	8	8	8	9
Total number of new sprouts	70	46	113	96	21	31	25	37	30	33
Mean number of new sprouts per treated tree (±s.d.)	7.8 ±4.4	5.1 ±3.7	12.6* ±4.8	12.0 ±7.9	2.6* ±2.1	3.4* ±3.5	3.1* ±1.9	4.1 ±3.3	3.3* ±3.0	3.7* ±3.2

* Mean values marked with an asterisk are significantly different from the control value mean at the $p = 0.05$ level in a two-tailed t test.

During the measurement of the new sprouts on the silver maple trees it was noticed that some sprouts originated on the main stem below the point of injection of the growth regulators, whilst others were found higher up the stem. Sterrett et al (1983) had earlier reported that some sprouting occurred below the injection site when six-year-old white ash and maple were injected with MBR 18337. In the present study new sprouts that had developed on pre-existing laterals which were joined to the main stem below the injection point, were classified as 'below' sprouts. All the new sprouts were reclassified as either being 'above' or 'below' the point of injection (see Table 2). The length of the various sprouts varied considerably from extremely short (~1 cm) to extremely long (~100 cm) and in order to determine if any of the growth regulators caused a change in the number of long, medium or short length sprouts produced, the frequency with which the various length sprouts were encountered was expressed graphically (Figures 1 and 2). For ease of plotting, the sprouts were grouped into classes of multiples of 4 cm, thus the first class was from 0 to 4 cm. In the control trees there were many sprouts originating above the injection point either 0 to 8 cm or 40 to 60 cm in length (Figure 1). No sprouts originating below the injection point were observed in the control trees. In trees treated with 0.2 mg/tree of MBR 18337 the frequency of distribution of the 'above' sprouts was similar to that encountered in the control. A few sprouts of variable length were found to originate below the injection point (Figure 1). With a higher dose of MBR 18337 (1.0 mg/tree) a large number of short sprouts were observed both above and below the injection point. With the highest dose of MBR 18337 (5.0 mg/tree) the vast majority of sprouts originating above the injection point were extremely short in length, and the peak of sprouts, of length 40 to 60 cm observed in the control, had almost completely disappeared. The three dose rates of EL-500 administered in these experiments all had radical effects in that almost all the 'above' sprouts observed were extremely small, whilst the few 'below' sprouts found were of variable length (Figure 2). Application of PP 333 also had a striking effect in that most of the 'above' sprouts were extremely short (Figure 2). The high dose of PP 333 (2.5 mg/tree) was the most effective, with approximately 85% of all the 'above' sprouts being 4 cm or less in length. All three doses of PP 333 seemed to have no obvious effect on the 'below' sprouts in that the distribution by class length of those observed appeared to be random. However, the highest dose of PP 333 (2.5 mg/tree) did produce more extremely short sprouts above the injection point that did the other two dose rates. The differences in the effects of the various growth regulators on the lengths of sprouts above and below the injection point in relation to the transport of the growth regulators upwards and downwards in the tree stem are discussed below.

The mean lengths of the sprouts originating either above or below the injection point, for each treatment, are given in

TABLE 2

EFFECTS OF TRUNK INJECTION OF VARIOUS AMOUNTS OF THE GROWTH REGULATORS MBR 18337, EL-500 AND PP 333 ON THE LENGTH OF NEW SPROUTS AND THE NUMBER OF INTERNODES PER UNIT LENGTH IN THOSE SPROUTS, IN PRUNED SILVER MAPLE TREES

Parameter	Control	MBR 18377 mg/tree			EL-500 mg/tree			PP 333 mg/tree		
		0.2	1.0	5.0	1.0	5.0	25.0	0.1	0.5	2.5
Number of trees treated	9	9	9	8	8	9	8	9	9	9
Total number of sprouts located above injection point	70	41	85	82	14	20	22	31	15	18
Total number of sprouts located below injection point	0	5	28	14	7	11	3	6	15	15
Mean length of sprouts located above injection point (±s.d.) cm	15.4 ±10.7	17.7 ±13.3	9.5 ±9.2	5.8 ±7.0	1.0* ±1.6	0.8* ±1.6	0.4* ±0.3	9.3 ±10.5	4.1* ±6.9	2.1* ±4.4
Mean length of sprouts located below injection point (±s.d.) cm	0	26.9 ±12.8	9.4 ±11.5	10.2 ±10.5	15.9 ±14.6	10.9 ±13.3	4.4 ±5.8	14.7 ±11.8	20.6 ±10.5	11.2 ±13.9
Total number of new sprout internodes	560	396	645	616	92	111	57	241	193	123
Mean number of internodes per cm sprout length, for sprouts above injection point (±s.d.)	0.39 ±0.48	0.40 ±0.43	0.67 ±.66	1.20* ±1.00	1.88* ±0.83	1.96* ±1.22	2.27* ±1.11	1.06 ±1.06	1.38* ±1.02	1.52* ±1.05
Mean number of internodes per cm sprout length, for sprouts below injection point (±s.d.)	0	0.17 ±0.05	0.79 ±0.95	0.58 ±0.49	0.65 ±0.67	0.66 ±0.63	0.89 ±0.63	0.47 ±0.56	0.24 ±0.17	0.78 ±0.65

* Mean values marked with an asterisk are significantly different from the mean value quoted directly below, at the p = 0.05 level in a two-tailed t test.

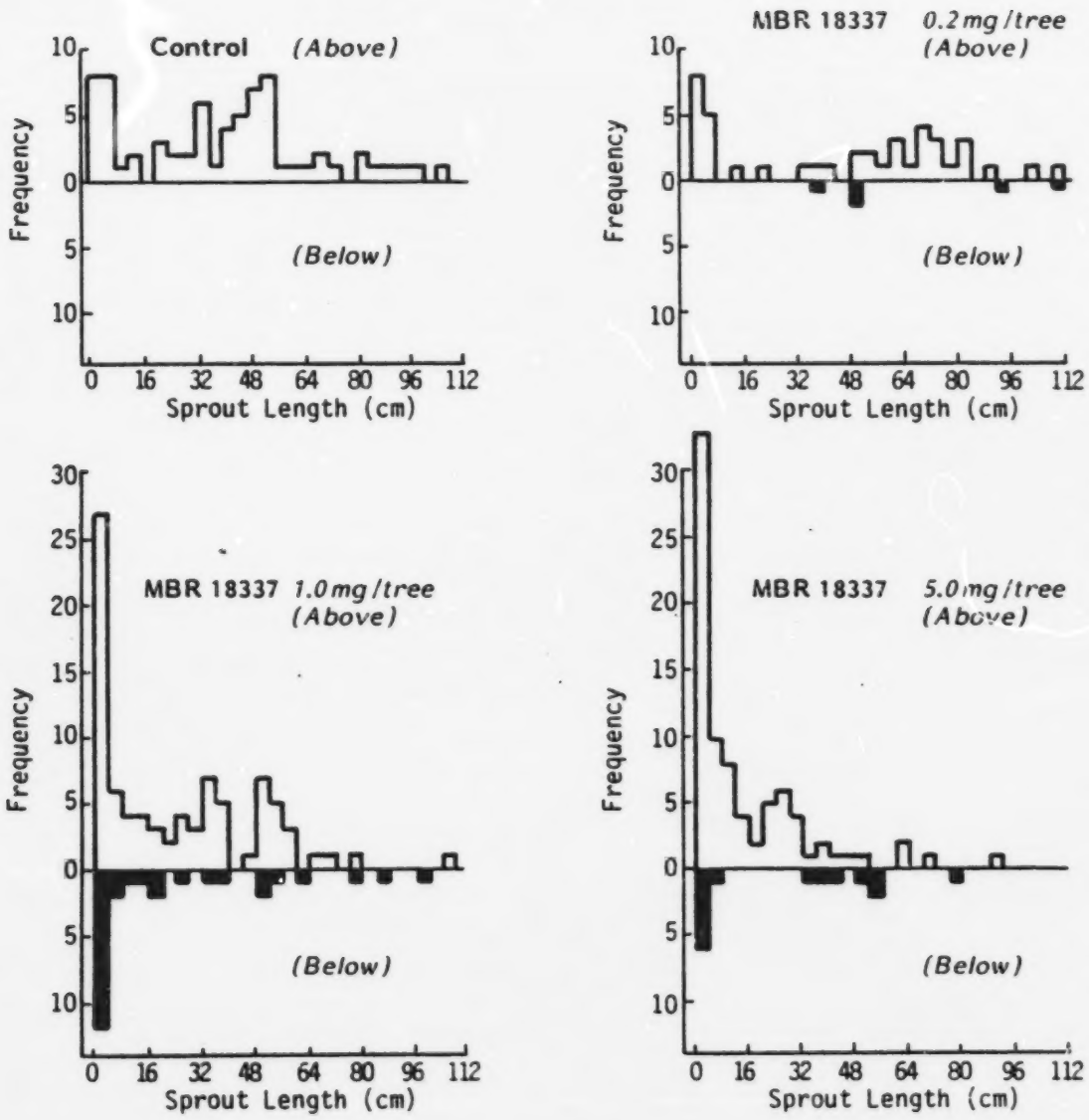

FIGURE 1

EFFECT OF TRUNK INJECTION OF THREE DIFFERENT AMOUNTS OF THE GROWTH REGULATOR MBR18337 ON THE LENGTH OF NEW SPROUTS, FORMED ABOVE AND BELOW THE INJECTION POINT, IN PRUNED SILVER MAPLE TREES

Sprouts were grouped according to length into various classes, each length class was 4 cm, classes were 0 to 4, 4 to 8 cm, etc.

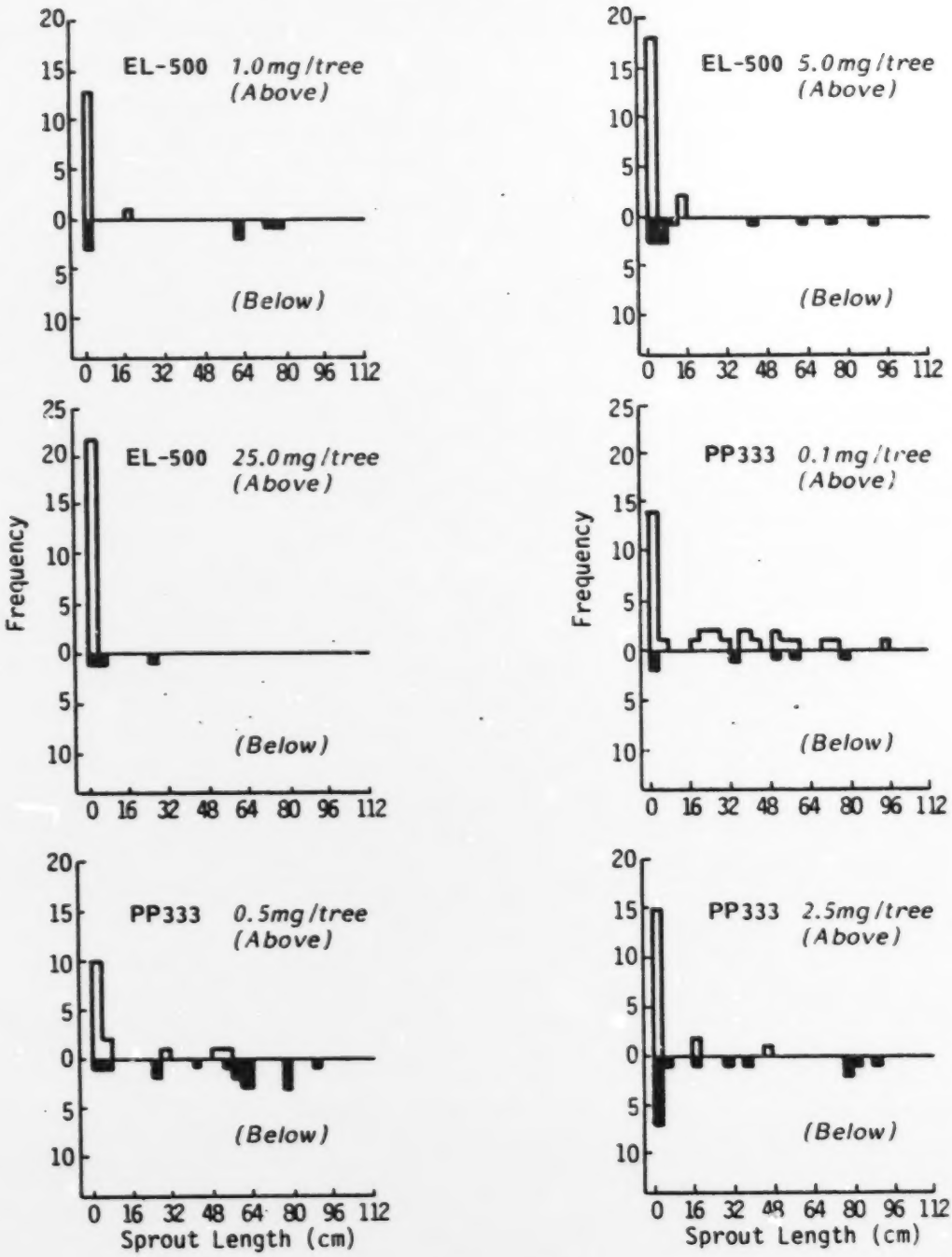

FIGURE 2

EFFECT OF TRUNK INJECTION OF THREE DIFFERENT AMOUNTS OF THE GROWTH REGULATOR EL-500 OR PP333 ON THE LENGTH OF NEW SPROUTS, FORMED ABOVE AND BELOW THE INJECTION POINT, IN PRUNED SILVER MAPLE TREES.

Sprouts were grouped according to length into various classes, each length class was 4 cm, classes were 0 to 4, 4 to 8 cm, etc.

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TABLE 3

a) EFFECTS OF TRUNK INJECTION OF VARIOUS GROWTH REGULATORS ON THE LENGTH OF SPROUTS PRODUCED ABOVE THE INJECTION POINT IN PRUNED SILVER MAPLE TREES

Treatment	Mean Sprout length †	Standard Deviation	Number of Sprouts	Source of Variation	One-Way Analysis of Variance Table (log + 1, Transformed Data) D.F.	S.S.	M.S.	F-Ratio
Control	3.265	1.156	70	Between treatments	9	275.02	30.56	21.35*
MBR 18337 0.2 mg	3.239	1.373	41	Within treatments	388	555.22	1.43	
MBR 18337 1.0 mg	2.558	1.344	85	Total	397	830.24		
MBR 18337 5.0 mg	2.127	1.170	82					
EL-500 1.0 mg	0.952	0.642	14					
EL-500 5.0 mg	0.784	0.684	20					
EL-500 25.0 mg	0.656	0.278	22					
PP 333 0.1 mg	2.322	1.513	31					
PP 333 0.5 mg	1.557	1.264	15					
PP 333 2.5 mg	1.088	1.032	18					

* indicates significance at the 5% level
† log + 1, transformed data

b) MULTIPLE RANGE TEST COMPARING MEAN SPROUT LENGTH (SPROUTS PRODUCED ABOVE INJECTION POINT) WITH VARIOUS GROWTH REGULATOR TREATMENTS USED

Treatment	EL-500 25.0 mg	EL-500 5.0 mg	EL-500 1.0 mg	PP 333 2.5 mg	PP 333 0.5 mg	MBR 18337 5.0 mg	PP 333 0.1 mg	MBR 18337 1.0 mg	MBR 18337 0.2 mg	Control
Mean Sprout Length	0.656	0.784	0.952	1.088	1.557	2.127	2.322	2.558	3.239	3.265

Mean sprout lengths which do not differ significantly have been underlined by the same bar, the significance level being 5%. Those mean sprout lengths which differ significantly are underlined by different bars.

Table 2. These data were log transformed and subjected to a one way analysis of variance (see Table 3A). There were statistically significant differences between the mean sprout length (of sprouts located above the injection point) for one or more of the various growth regulator treatments and the mean sprout length observed in either another treatment or in the control at the 5% confidence level. A multiple range test conducted on the data suggests that the various growth regulator treatments can be divided into several groups in terms of effectiveness in retarding the growth of sprouts produced above the injection point (see Table 3B). All three dose rates of EL-500 and the two higher doses of PP 333 were placed in a group whose members significantly reduced the length of sprouts produced. The low dose of MBR 18337 (0.2 mg/tree) did not significantly reduce the length of sprouts produced. The remaining growth regulator treatments were placed in a third group, distinct from the first group mentioned above but whose members also significantly reduced sprout growth.

The mean lengths of sprouts originating below the injection point, for each growth regulator treatment, are given in Table 2. When these data were subjected to a one way analysis of variance, the F-ratio value obtained was only just significant at the 5% level (data not shown). A multiple range test conducted on the data failed to show any significant differences in the effectiveness of the various treatments (data not shown). It should be remembered that the control trees had no sprouts originating below the injection point (Table 2) and thus all the treatments were indeed effective in one sense in that they caused such sprouts to be produced.

From the above discussion it is apparent that some of the growth regulator treatments were effective in significantly reducing the length of sprouts produced above the injection point, whilst those produced below the injection point did not appear to be so affected. It should be remembered that the control trees had no sprouts below the injection point and thus no comparison can be made between the control and the treated trees. However, it is possible to compare the length of sprouts on treated trees produced above the injection point with those produced below. It may be possible to distinguish differences in the effects of the growth regulators, in that some may affect sprouts above and below the injection point, whilst others may affect only one of the two types. Analysis of the data revealed that all dose rates of EL-500 and the two higher doses of PP 333 resulted in significantly shorter mean length sprouts above the injection point than below (see Table 2). With all dose rates of MBR 18337 there were no differences between the mean length of the two types of sprouts. These data would suggest that both

EL-500 and PP 333 move predominantly upwards in the stem whilst MBR 18337 moves in both directions.

From the data presented in Table 2 it appeared that some or all the growth regulators were affecting the number of internodes, expressed on a per unit length basis, present in the sprouts produced above the injection point. The effects of the various growth regulator treatments on the number of internodes forms per unit length in the sprouts was examined statistically by subjecting the data obtained to a one way analysis of variance (Table 4A). The F-ratio value obtained was significant at the 5% level. A multiple range test conducted on the data (Table 4B) suggests that the various growth regulator treatments can be divided into several groups in terms of effectiveness in increasing the number of internodes per unit length present in the sprouts produced above the injection point. The lowest dose of MBR 18337 (0.2 mg/tree) did not significantly affect the number of internodes per unit length in the sprouts, whilst all the remaining treatments did. The most effective treatments were all the dose rates of EL-500 and the highest dose of PP 333 used (Table 4B).

The effects of the growth regulators on the number of internodes per unit length in sprouts produced below the injection point were also examined statistically. The data were subjected to a one way analysis of variance. The F-ratio value obtained was not significant at the 5% level (data not shown) and so a multiple range test was not conducted.

From the data on the number of internodes per unit length, it appeared that the sprouts produced above the injection point had more internodes per unit length than sprouts produced below (Table 2). Analysis of the data revealed that for all the dose rates of EL-500, the two higher dose rates of PP 333, and the highest dose rate of MBR 18337 used, there were significantly more internodes per unit length in sprouts produced above the injection point than below. The differences between the two types of sprouts with the remaining dose rates of MBR 18337 and PP 333 were not significant. These results confirm that after injection of the growth regulators EL-500 and PP 333, movement of the chemicals is predominantly upwards. The fact that the highest dose rate of MBR 18337 also appeared to move in a predominantly upwards direction is somewhat confusing, given the report by Sterrett et al (1983) that this chemical may be ambimobile, moving both upwards in the xylem and downwards in the phloem. The data on sprout length presented in Table 2 suggest that at the highest dose MBR 18337 does indeed move both upwards and downwards in the stem.

TABLE 4

a) EFFECTS OF TRUNK INJECTION OF VARIOUS GROWTH REGULATORS ON THE NUMBER OF INTERNODES PER UNIT SPROUT LENGTH, FOR SPROUTS PRODUCED ABOVE THE INJECTION POINT, IN PRUNED SILVER MAPLE TREES

Treatment	Mean Number of internodes/cm†	Standard Deviation	Number of Sprouts	Source of Variation	One-Way Analysis of Variance Table (log + 1, Transformed Data) D.F.	S.S.	M.S.	F-Ratio
Control	0.294	0.244	70	Between treatments	9	26.64	2.96	24.44*
MBR 18337 0.2 mg	0.301	0.245	41	Within treatments	388	46.98	0.12	
MBR 18337 1.0 mg	0.452	0.334	85	Total	397	73.62		
MBR 18337 5.0 mg	0.702	0.410	82					
EL-500 1.0 mg	1.017	0.292	14					
EL-500 5.0 mg	1.012	0.390	20					
EL-500 25.0 mg	1.133	0.333	22					
PP 333 0.1 mg	0.612	0.460	31					
PP 333 0.5 mg	0.786	0.417	15					
PP 333 2.5 mg	0.853	0.376	18					

* indicates significance at the 5% level
† log + 1, transformed data

b) MULTIPLE RANGE TEST COMPARING MEAN NUMBER OF INTERNODES PER CM SPROUT LENGTH (SPROUTS PRODUCED ABOVE INJECTION POINT) WITH VARIOUS GROWTH REGULATOR TREATMENTS USED

Treatment	Control	MBR 18337 0.2 mg	MBR 18337 1.0 mg	PP 333 0.1 mg	MBR 18337 5.0 mg	PP 333 0.5 mg	PP 333 2.5 mg	EL-500 5.0 mg	EL-500 1.0 mg	EL-500 25.0 mg
Mean Number Internodes/cm	0.294	0.301	0.452	0.612	0.702	0.786	0.853	1.012	1.017	1.133

Mean number of internodes per cm sprout length which do not differ significantly have been underlined by the same bar, the significance level being 5%. Those mean number of internodes per cm which differ significantly are underlined by different bars.

The present study has demonstrated that trunk injection of the three growth regulators MBR18337, EL500 and PP333 resulted in a significant reduction in the length of sprouts produced on pruned silver maple trees, with the latter two chemicals being the more effective. The effects of trunk injection of these growth regulators in other tree species, and over two or three growing seasons, remains to be determined. The importance of time-of-year of application of the growth regulators, which is thought to have a significant effect on the potency of these chemicals (CEA, 1982), should also be addressed.

4.0 CONCLUSIONS

1. Trunk injection of methanolic solutions of the growth regulators MBR 18337, EL-500 and PP 333 into pruned two-year-old silver maple trees grown in the greenhouse resulted in the production of significantly shorter sprouts at the end of the three month experimental period than in control trees. Both EL-500 and PP333 caused a significant decrease in the number of sprouts found on the experimental trees.

2. Treatment with all three growth regulators resulted in sprouts being produced both above and below the injection point on the tree stems, whilst sprouts were only produced above the injection point on the control trees.

3. On the basis of the differential effects of the growth regulators on the mean length of sprouts produced above and below the injection point, it appears that both EL-500 and PP 333 were translocated in primarily an upward direction after application, whilst MBR 18337 was translocated in both an upward and a downward direction.

4. High doses of MBR 18337 (5 mg/tree) caused initial sprout growth to be distorted, with twisted and cupped leaves. Later in the experiment the foliage appeared normal. Lower doses of MBR 18337 and all the doses of EL-500 and PP 333 used did not have such a phytotoxic effect.

5. The effects of trunk injection of both the growth regulators EL-500 and PP 333 on sprout growth should be examined in the field in trees of various species that constitute a problem under distribution lines on city streets in Ontario.

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Technical Data Sheet, PP 333 (1984) Chipman Inc, Stoney Creek, Ontario.

APPENDIX A

PP 333

PP 333 [common name paclobutrazol; (2R,3R+2S,3S)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl)pentan-3-ol] was a gift from Mr. B. Smith, Chipman Inc, Stoney Creek, Ontario. PP 333 is an experimental plant growth regulator being developed worldwide by ICI Plant Protection Division. It is an inhibitor of gibberellin biosynthesis which results in long-term retardation and internode compression in a wide range of monocot and dicot crops and woody plants. PP 333 shows little phloem mobility rather moving upwards in the xylem. The solution of PP 333 in methanol provided by Chipman (Technical formulation 9017), contained 75 g/L (active ingredient). This concentrated stock solution was diluted with methanol to give the appropriate weight of active ingredient in an injection volume of 50 µL.

MBR 18337

MBR 18337 [no common name; {N-[4-(ethylthio)-2-(trifluoromethyl)phenyl]-methane-sulfonamide} was a gift from Mr. D.W. Parker 3M Agricultural Products, St. Paul, Minnesota. MBR 18337 is thought to have a mode of action similar to that of dikegulac in that it is ambimobile, moving in both the phleom and the xylem (Sterrett et al, 1983) and appears to inhibit apical meristematic activity (Roberts et al, 1979). The fomulation supplied by 3M was an emulsifiable concentrate (2-EC) lot number XM-63,5/11 containing 240 g/L (active ingredient). This concentrate was diluted with methanol to give the appropriate weight of active ingredient in an injection volum of 50 µL.

EL-500

EL-500 [common name flurprimidol; α-(1-methylethyl)-α-[4-(trifluoromethoxy)phenyl]-5-pyrimidine-methanol] was a gift from Elanco, a Division of Eli Lilly Canada Inc, London, Ontario. EL-500 is a foliar and root active growth regulator which reduces internode elongation of a broad range of both monocots and dicots. The mechanism of action involves a reduction in the biosynthesis of gibberellins. Support for this is found in the reversibility of EL-500's growth regulating effect by foliar application of gibberellic acid to inhibited plants. The EL-500 stock solution contained 500 g/L (active ingredient). This stock solution (lot number Z-10082) was diluted with methanol to give the appropriate weight of active ingredient in an injection volume of 50 µL.